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Chip Seal Finite Element Model

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ABSTRACT: This paper describes the preliminary development of a 3-D finite element model of a chip seal road surfacing. A 3-D chip matrix was constructed using X-ray tomography scans of multiple layer seal samples removed from a highway in New Zealand. Care was taken to minimize smoothing of the chip surfaces and to obtain accurate rendering of chip to chip contact points. The model was implemented using the ABAQUS finite element package. Aggregate particles were modeled as rigid bodies; the bitumen was modeled using a viscoelastic constitutive model. Constants for the bitumen model were determined by back- calculation from experimental measurements made using a dynamically loaded ball bearing assembly simulating a chip seal. Results from the equivalent geometry implemented in ABAQUS, were compared to the experimental data using an iterative process to optimize the model constants. The model will be used to study the effect of bitumen type and seal design on seal cohesion and stability.

1 INTRODUCTION

Chip seals provide a cost-effective road surfacing particularly in low traffic environments. Despite their widespread use there is however a lack of basic knowledge that quantitatively relates the physical properties of chip seal binders to various seal failure modes (such as chip loss or cracking) and this is a current area of research. A major difficulty in studying seal performance in the laboratory is the problem of constructing test seals that are realistic and reproducible. An alternative to physically constructing seals is to use a finite element model to calculate stress-strain data within the seal under traffic loading. Such a model would allow the effect of factors such as binder type and traffic stress on likely seal performance to be studied relatively simply This paper describes work undertaken to construct a preliminary chip seal 3D FEM using data derived from a real seal surface.

Previous workers have developed a seal FEM in which the chips were represented by regular ellipsoids arranged in a single layer and without chip to chip contact (Huurman 2010, Milne *et.al, 2004*). Chip to chip interactions are likely to be critical for the distribution of horizontal loads over the seal surface that enables the seal to withstand traffic stresses In the present work an attempt was made to develop a more realistic seal structure by modeling chip to chip contacts and chip orientations derived from a real multiple layer seal using x-ray tomography data. In this preliminary work a non-linear viscoelastic material model used to describe bitumen behaviour in the FEM. The bitumen model constants were back-calculated from physical measurements.

2 CONSTRUCTION OF THE MODEL

2.1 *Geometry*

The chip skeleton for the model was constructed by recombining x-ray tomography cross sections of a real multiple layer chip seal core. This technique has been widely used in the study of asphalt mix (Kutay *et al*. 2010, Zelelew & Papagiannakis 2011). Seal cores (Figure 1a) were removed and analysed by x-ray tomography courtesy of Professor Bahia at the University of Wisconsin-Madison and the FHWA Turner-Fairbank Highway Research Center. Horizontal cross section scans were taken at 1.0 mm intervals and converted to grayscale TIFF images (Figure 1b).